SERVLET BASICS

Topics in This Chapter

- The basic structure of servlets
- A simple servlet that generates plain text
- A servlet that generates HTML
- Servlets and packages
- Some utilities that help build HTML
- The servlet life cycle
- How to deal with multithreading problems
- Tools for interactively talking to servlets
- Servlet debugging strategies

Chapter 3

As discussed in Chapter 1, servlets are programs that run on a Web or application server and act as a middle layer between a request coming from a Web browser or other HTTP client and databases or applications on the HTTP server. Their job is to perform the following tasks, as illustrated in Figure 3–1.

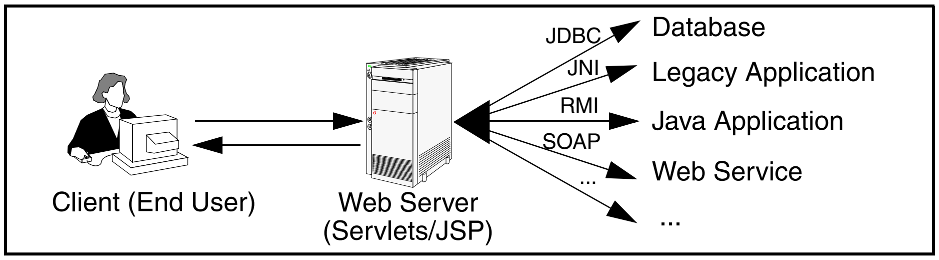


Figure 3–1 The role of Web middleware.

1. **Read the explicit data sent by the client.**
   The end user normally enters this data in an HTML form on a Web page. However, the data could also come from an applet or a custom HTTP client program.
2. **Read the implicit HTTP request data sent by the browser.**
   Figure 3–1 shows a single arrow going from the client to the Web server (the layer in which servlets and JSP pages execute), but there are really *two* varieties of data: the explicit data the end user enters in

a form and the behind-the-scenes HTTP information. Both types of data are critical to effective development. The HTTP information includes cookies, media types and compression schemes the browser understands, and so forth; it is discussed in Chapter 5.

3. **Generate the results.**
   This process may require talking to a database, executing an RMI or CORBA call, invoking a Web service, or computing the response directly. Your real data may be in a relational database. Fine. But your database probably doesn't speak HTTP or return results in HTML, so the Web browser can't talk directly to the database. The same argument applies to most other applications. You need the Web middle layer to extract the incoming data from the HTTP stream, talk to the application, and embed the results inside a document.
4. **Send the explicit data (i.e., the document) to the client.**
   This document can be sent in a variety of formats, including text (HTML or XML), binary (GIF images), Excel, or even a compressed format like gzip that is layered on top of some other underlying format.
5. **Send the implicit HTTP response data.**
   Figure 3–1 shows a single arrow going from the Web middle layer (the servlet or JSP page) to the client, but there are really *two* varieties of data sent: the document itself and the behind-the-scenes HTTP information. Both types of data are critical to effective development. Sending HTTP response data involves telling the browser or other client what type of document is being returned (e.g., HTML), setting cookies and caching parameters, and other such tasks. These tasks are discussed in Chapters 6–8.

In principle, servlets are not restricted to Web or application servers that handle HTTP requests but can be used for other types of servers as well. For example, servlets could be embedded in FTP or mail servers to extend their functionality. In practice, however, this use of servlets has not caught on, and we discuss only HTTP servlets.

3.1 Basic Servlet Structure

Listing 3.1 outlines a basic servlet that handles GET requests. GET requests, for those unfamiliar with HTTP, are the usual type of browser requests for Web pages. A browser generates this request when the user enters a URL on the address line, follows a link from a Web page, or submits an HTML form that either does not specify a METHOD or specifies METHOD="GET". Servlets can also easily handle POST requests, which are generated when someone submits an HTML form that specifies METHOD="POST". For details on the use of HTML forms and the distinctions between GET and POST, see Chapter 19 (Creating and Processing HTML Forms).

Listing 3.1 ServletTemplate.java

```
import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;

public class ServletTemplate extends HttpServlet {
  public void doGet(HttpServletRequest request,
                    HttpServletResponse response)
      throws ServletException, IOException {

    // Use "request" to read incoming HTTP headers
    // (e.g., cookies) and query data from HTML forms.

    // Use "response" to specify the HTTP response status
    // code and headers (e.g., the content type, cookies).

    PrintWriter out = response.getWriter();
    // Use "out" to send content to browser.
  }
}
```

Servlets typically extend HttpServlet and override doGet or doPost, depending on whether the data is being sent by GET or by POST. If you want a servlet to take the same action for both GET and POST requests, simply have doGet call doPost, or vice versa.

Both doGet and doPost take two arguments: an HttpServletRequest and an HttpServletResponse. The HttpServletRequest lets you get at all of the *incoming* data; the class has methods by which you can find out about information such as form (query) data, HTTP request headers, and the client's hostname. The HttpServletResponse lets you specify *outgoing* information such as HTTP status codes (200, 404, etc.) and response headers (Content-Type, Set-Cookie, etc.). Most importantly, HttpServletResponse lets you obtain a PrintWriter that you use to send document content back to the client. For simple servlets, most of the effort is spent in println statements that generate the desired page. Form data, HTTP request headers, HTTP responses, and cookies are all discussed in the following chapters.

Since `doGet` and `doPost` throw two exceptions (`ServletException` and `IOException`), you are required to include them in the method declaration. Finally, you must import classes in `java.io` (for `PrintWriter`, etc.), `javax.servlet` (for `HttpServlet`, etc.), and `javax.servlet.http` (for `HttpServletRequest` and `HttpServletResponse`).

However, there is no need to memorize the method signature and import statements. Instead, simply download the preceding template from the source code archive at http://www.coreservlets.com/ and use it as a starting point for your servlets.

3.2 A Servlet That Generates Plain Text

Listing 3.2 shows a simple servlet that outputs plain text, with the output shown in Figure 3–2. Before we move on, it is worth spending some time reviewing the process of installing, compiling, and running this simple servlet. See Chapter 2 (Server Setup and Configuration) for a much more detailed description of the process.

First, be sure that you've already verified the basics:

- That your server is set up properly as described in Section 2.3 (Configure the Server).
- That your development `CLASSPATH` refers to the necessary three entries (the servlet JAR file, your top-level development directory, and ".") as described in Section 2.7 (Set Up Your Development Environment).
- That all of the test cases of Section 2.8 (Test Your Setup) execute successfully.

Second, type "`javac HelloWorld.java`" or tell your development environment to compile the servlet (e.g., by clicking Build in your IDE or selecting Compile from the emacs JDE menu). This step will compile your servlet to create HelloWorld.class.

Third, move HelloWorld.class to the directory that your server uses to store servlets that are in the default Web application. The exact location varies from server to server, but is typically of the form *install_dir*/.../WEB-INF/classes (see Section 2.10 for details). For Tomcat you use *install_dir*/webapps/ROOT/WEB-INF/classes, for JRun you use *install_dir*/servers/default/default-ear/default-war/WEB-INF/classes, and for Resin you use *install_dir*/doc/WEB-INF/classes. Alternatively, you can use one of the techniques of Section 2.9 (Establish a Simplified Deployment Method) to automatically place the class files in the appropriate location.

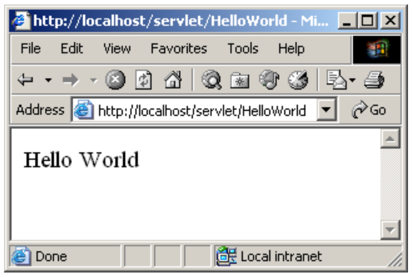
Finally, invoke your servlet. This last step involves using either the default URL of http://*host*/servlet/*ServletName* or a custom URL defined in the web.xml file as described in Section 2.11 (Web Applications: A Preview). During initial development, you will almost certainly find it convenient to use the default URL so that you don't have to edit the web.xml file each time you test a new servlet. When you deploy real applications, however, you almost always disable the default URL and assign explicit URLs in the web.xml file (see Section 2.11, "Web Applications: A Preview"). In fact, servers are not absolutely required to support the default URL, and a few, most notably BEA WebLogic, do not.

Figure 3–2 shows the servlet being accessed by means of the default URL, with the server running on the local machine.

Listing 3.2 HelloWorld.java

```
import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;

public class HelloWorld extends HttpServlet {
  public void doGet(HttpServletRequest request,
                    HttpServletResponse response)
      throws ServletException, IOException {
    PrintWriter out = response.getWriter();
    out.println("Hello World");
  }
}
```


http://localhost/servlet/HelloWorld - Mi...
File Edit View Favorites Tools Help
Address http://localhost/servlet/HelloWorld
Go
Done
Local intranet

Hello World

Figure 3–2 Result of http://localhost/servlet/HelloWorld.

3.3 A Servlet That Generates HTML

Most servlets generate HTML, not plain text as in the previous example. To generate HTML, you add three steps to the process just shown:

1. Tell the browser that you're sending it HTML.
2. Modify the `println` statements to build a legal Web page.
3. Check your HTML with a formal syntax validator.

You accomplish the first step by setting the HTTP `Content-Type` response header to `text/html`. In general, headers are set by the `setHeader` method of `HttpServletResponse`, but setting the content type is such a common task that there is also a special `setContentType` method just for this purpose. The way to designate HTML is with a type of `text/html`, so the code would look like this:

```
response.setContentType("text/html");
```

Although HTML is the most common kind of document that servlets create, it is not unusual for servlets to create other document types. For example, it is quite common to use servlets to generate Excel spreadsheets (content type `application/vnd.ms-excel`—see Section 7.3), JPEG images (content type `image/jpeg`—see Section 7.5), and XML documents (content type `text/xml`). Also, you rarely use servlets to generate HTML pages that have relatively fixed formats (i.e., whose layout changes little for each request); JSP is usually more convenient in such a case. JSP is discussed in Part II of this book (starting in Chapter 10).

Don't be concerned if you are not yet familiar with HTTP response headers; they are discussed in Chapter 7. However, you should note now that you need to set response headers *before* actually returning any of the content with the `PrintWriter`. That's because an HTTP response consists of the status line, one or more headers, a blank line, and the actual document, *in that order*. The headers can appear in any order, and servlets buffer the headers and send them all at once, so it is legal to set the status code (part of the first line returned) even after setting headers. But servlets do not necessarily buffer the document itself, since users might want to see partial results for long pages. Servlet engines are permitted to partially buffer the output, but the size of the buffer is left unspecified. You can use the `getBufferSize` method of `HttpServletResponse` to determine the size, or you can use `setBufferSize` to specify it. You can set headers until the buffer fills up and is actually sent to the client. If you aren't sure whether the buffer has been sent, you can use the `isCommitted` method to check. Even so, the best approach is to simply put the `setContentType` line before any of the lines that use the `PrintWriter`.

Core Warning

*You must set the content type **before** transmitting the actual document.*

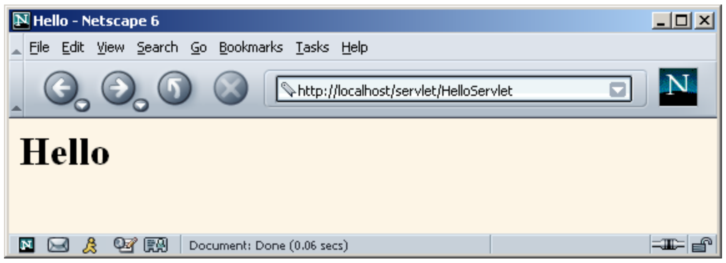
The second step in writing a servlet that builds an HTML document is to have your `println` statements output HTML, not plain text. Listing 3.3 shows HelloServlet.java, the sample servlet used in Section 2.8 to verify that the server is functioning properly. As Figure 3–3 illustrates, the browser formats the result as HTML, not as plain text.

Listing 3.3 HelloServlet.java

```
import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;

/** Simple servlet used to test server. */

public class HelloServlet extends HttpServlet {
  public void doGet(HttpServletRequest request,
                    HttpServletResponse response)
      throws ServletException, IOException {
    response.setContentType("text/html");
    PrintWriter out = response.getWriter();
    String docType =
      "<!DOCTYPE HTML PUBLIC \"-//W3C//DTD HTML 4.0 " +
      "Transitional//EN\">\n";
    out.println(docType +
                "<HTML>\n" +
                "<HEAD><TITLE>Hello</TITLE></HEAD>\n" +
                "<BODY BGCOLOR=\"#FDF5E6\">\n" +
                "<H1>Hello</H1>\n" +
                "</BODY></HTML>");
  }
}
```


Hello - Netscape 6
File Edit View Search Go Bookmarks Tasks Help
http://localhost/servlet/HelloServlet
Document: Done (0.06 secs)

Hello

Figure 3–3 Result of `http://localhost/servlet/HelloServlet`.

The final step is to check that your HTML has no syntax errors that could cause unpredictable results on different browsers. See Section 3.5 (Simple HTML-Building Utilities) for a discussion of HTML validators.

3.4 Servlet Packaging

In a production environment, multiple programmers can be developing servlets for the same server. So, placing all the servlets in the same directory results in a massive, hard-to-manage collection of classes and risks name conflicts when two developers inadvertently choose the same name for a servlet or a utility class. Now, Web applications (see Section 2.11) help with this problem by dividing things up into separate directories, each with its own set of servlets, utility classes, JSP pages, and HTML files. However, since even a single Web application can be large, you still need the standard Java solution for avoiding name conflicts: packages. Besides, as you will see later, custom classes used by JSP pages should *always* be in packages. You might as well get in the habit early.

When you put your servlets in packages, you need to perform the following two additional steps.

1. **Place the files in a subdirectory that matches the intended package name.** For example, we'll use the `coreservlets` package for most of the rest of the servlets in this book. So, the class files need to go in a subdirectory called `coreservlets`. Remember that case matters for both package names and directory names, regardless of what operating system you are using.
2. **Insert a package statement in the class file.** For instance, for a class to be in a package called `somePackage`, the class should be in the `somePackage` directory and the *first* non-comment line of the file should read

```
package somePackage;
```

For example, Listing 3.4 presents a variation of the `HelloServlet` class that is in the `coreservlets` package and thus the coreservlets directory. As discussed in Section 2.8 (Test Your Setup), the class file should be placed in *install_dir*/webapps/ROOT/WEB-INF/classes/coreservlets for Tomcat, *install_dir*/servers/default/default-ear/default-war/WEB-INF/classes/coreservlets for JRun, and *install_dir*/doc/WEB-INF/classes/coreservlets for Resin. Other servers have similar installation locations.

Figure 3–4 shows the servlet accessed by means of the default URL.

Listing 3.4 coreservlets/HelloServlet2.java

```
package coreservlets;

import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;

/** Simple servlet for testing the use of packages. */

public class HelloServlet2 extends HttpServlet {
  public void doGet(HttpServletRequest request,
                    HttpServletResponse response)
      throws ServletException, IOException {
    response.setContentType("text/html");
    PrintWriter out = response.getWriter();
    String docType =
      "<!DOCTYPE HTML PUBLIC \"-//W3C//DTD HTML 4.0 " +
      "Transitional//EN\">\n";
    out.println(docType +
                "<HTML>\n" +
                "<HEAD><TITLE>Hello (2)</TITLE></HEAD>\n" +
                "<BODY BGCOLOR=\"#FDF5E6\">\n" +
                "<H1>Hello (2)</H1>\n" +
                "</BODY></HTML>");
  }
}
```

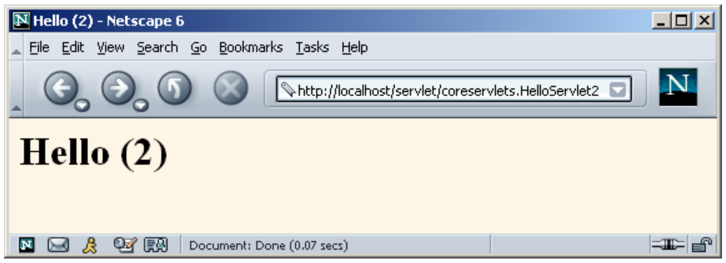

Hello (2) - Netscape 6
File Edit View Search Go Bookmarks Tasks Help
http://localhost/servlet/coreservlets.HelloServlet2
Hello (2)
Document: Done (0.07 secs)

Figure 3–4 Result of http://localhost/servlet/coreservlets.HelloServlet2.

3.5 Simple HTML-Building Utilities

As you probably already know, an HTML document is structured as follows:

```
<!DOCTYPE ...>
<HTML>
<HEAD><TITLE>...</TITLE>...</HEAD>
<BODY ...>...</BODY>
</HTML>
```

When using servlets to build the HTML, you might be tempted to omit part of this structure, especially the DOCTYPE line, noting that virtually all major browsers ignore it even though the HTML specifications require it. We strongly discourage this practice. The advantage of the DOCTYPE line is that it tells HTML validators which version of HTML you are using so they know which specification to check your document against. These validators are valuable debugging services, helping you catch HTML syntax errors that your browser guesses well on but that other browsers will have trouble displaying.

The two most popular online validators are the ones from the World Wide Web Consortium (http://validator.w3.org/) and from the Web Design Group (http://www.htmlhelp.com/tools/validator/). They let you submit a URL, then they retrieve the page, check the syntax against the formal HTML specification, and report any errors to you. Since, to a client, a servlet that generates HTML looks exactly like a regular Web page, it can be validated in the normal manner unless it requires POST data to return its result. Since GET data is attached to the URL, you can even send the validators a URL that includes GET data. If the servlet is available only inside your corporate firewall, simply run it, save the HTML to disk, and choose the validator's File Upload option.

Core Approach

Use an HTML validator to check the syntax of pages that your servlets generate.

Admittedly, it is sometimes a bit cumbersome to generate HTML with `println` statements, especially long tedious lines like the `DOCTYPE` declaration. Some people address this problem by writing lengthy HTML-generation utilities, then use the utilities throughout their servlets. We're skeptical of the usefulness of such an extensive library. First and foremost, the inconvenience of generating HTML programmatically is one of the main problems addressed by JavaServer Pages (see Chapter 10, "Overview of JSP Technology"). Second, HTML generation routines can be cumbersome and tend not to support the full range of HTML attributes (`CLASS` and `ID` for style sheets, JavaScript event handlers, table cell background colors, and so forth).

Despite the questionable value of a full-blown HTML generation library, if you find you're repeating the same constructs many times, you might as well create a simple utility class that simplifies those constructs. After all, you're working with the Java programming language; don't forget the standard object-oriented programming principle of reusing, not repeating, code. Repeating identical or nearly identical code means that you have to change the code lots of different places when you inevitably change your approach.

For standard servlets, two parts of the Web page (`DOCTYPE` and `HEAD`) are unlikely to change and thus could benefit from being incorporated into a simple utility file. These are shown in Listing 3.5, with Listing 3.6 showing a variation of the `HelloServlet` class that makes use of this utility. We'll add a few more utilities throughout the book.

Listing 3.5 coreservlets/ServletUtilities.java

```
package coreservlets;

import javax.servlet.*;
import javax.servlet.http.*;

/** Some simple time savers. Note that most are static methods. */

public class ServletUtilities {
  public static final String DOCTYPE =
    "<!DOCTYPE HTML PUBLIC \"-//W3C//DTD HTML 4.0 " +
    "Transitional//EN\">";
```

Listing 3.5 coreservlets/ServletUtilities.java *(continued)*

```
  public static String headWithTitle(String title) {
    return(DOCTYPE + "\n" +
           "<HTML>\n" +
           "<HEAD><TITLE>" + title + "</TITLE></HEAD>\n");
  }

  ...
}
```

Listing 3.6 coreservlets/HelloServlet3.java

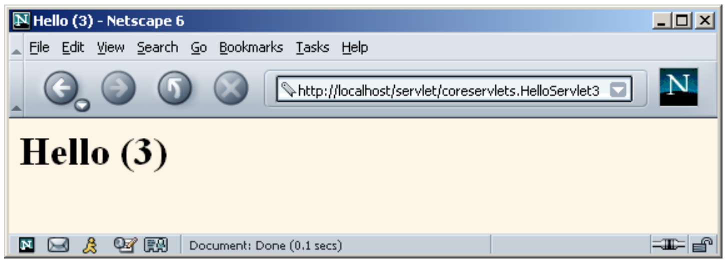
```
package coreservlets;

import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;

/** Simple servlet for testing the use of packages
 *  and utilities from the same package.
 */

public class HelloServlet3 extends HttpServlet {
  public void doGet(HttpServletRequest request,
                    HttpServletResponse response)
      throws ServletException, IOException {
    response.setContentType("text/html");
    PrintWriter out = response.getWriter();
    String title = "Hello (3)";
    out.println(ServletUtilities.headWithTitle(title) +
                "<BODY BGCOLOR=\"#FDF5E6\">\n" +
                "<H1>" + title + "</H1>\n" +
                "</BODY></HTML>");
  }
}
```

After you compile HelloServlet3.java (which results in ServletUtilities.java being compiled automatically), you need to move the two class files to the coreservlets subdirectory of the server's default deployment location (.../WEB-INF/classes; review Section 2.8 for details). If you get an "Unresolved symbol" error when compiling HelloServlet3.java, go back and review the CLASSPATH settings described in Section 2.7 (Set Up Your Development Environment), especially the part about including the top-level development directory in the CLASSPATH. Figure 3–5 shows the result when the servlet is invoked with the default URL.


Hello (3) - Netscape 6
File Edit View Search Go Bookmarks Tasks Help
http://localhost/servlet/coreservlets.HelloServlet3
Document: Done (0.1 secs)

Hello (3)

Figure 3–5 Result of `http://localhost/servlet/coreservlets.HelloServlet3`.

3.6 The Servlet Life Cycle

In Section 1.4 (The Advantages of Servlets Over "Traditional" CGI) we referred to the fact that only a single instance of each servlet gets created, with each user request resulting in a new thread that is handed off to `doGet` or `doPost` as appropriate. We'll now be more specific about how servlets are created and destroyed, and how and when the various methods are invoked. We summarize here, then elaborate in the following subsections.

When the servlet is first created, its `init` method is invoked, so `init` is where you put one-time setup code. After this, each user request results in a thread that calls the `service` method of the previously created instance. Multiple concurrent requests normally result in multiple threads calling `service` simultaneously, although your servlet can implement a special interface (`SingleThreadModel`) that stipulates that only a single thread is permitted to run at any one time. The `service` method then calls `doGet`, `doPost`, or another `do`*`Xxx`* method, depending on the type of HTTP request it received. Finally, if the server decides to unload a servlet, it first calls the servlet's `destroy` method.

The service Method

Each time the server receives a request for a servlet, the server spawns a new thread and calls `service`. The `service` method checks the HTTP request type (`GET`, `POST`, `PUT`, `DELETE`, etc.) and calls `doGet`, `doPost`, `doPut`, `doDelete`, etc., as appropriate. A `GET` request results from a normal request for a URL or from an HTML form that has no `METHOD` specified. A `POST` request results from an HTML form that specifically lists `POST` as the `METHOD`. Other HTTP requests are generated only by custom clients. If you aren't familiar with HTML forms, see Chapter 19 (Creating and Processing HTML Forms).

Now, if you have a servlet that needs to handle both POST and GET requests identically, you may be tempted to override service directly rather than implementing both doGet and doPost. This is not a good idea. Instead, just have doPost call doGet (or vice versa), as below.

```
public void doGet(HttpServletRequest request,
                  HttpServletResponse response)
    throws ServletException, IOException {
  // Servlet code
}

public void doPost(HttpServletRequest request,
                   HttpServletResponse response)
    throws ServletException, IOException {
  doGet(request, response);
}
```

Although this approach takes a couple of extra lines of code, it has several advantages over directly overriding service. First, you can later add support for other HTTP request methods by adding doPut, doTrace, etc., perhaps in a subclass. Overriding service directly precludes this possibility. Second, you can add support for modification dates by adding a getLastModified method, as illustrated in Listing 3.7. Since getLastModified is invoked by the default service method, overriding service eliminates this option. Finally, service gives you automatic support for HEAD, OPTION, and TRACE requests.

Core Approach

If your servlet needs to handle both GET and POST identically, have your doPost method call doGet, or vice versa. Don't override service.

The doGet, doPost, and doXxx Methods

These methods contain the real meat of your servlet. Ninety-nine percent of the time, you only care about GET or POST requests, so you override doGet and/or doPost. However, if you want to, you can also override doDelete for DELETE requests, doPut for PUT, doOptions for OPTIONS, and doTrace for TRACE. Recall, however, that you have automatic support for OPTIONS and TRACE.

Normally, you do not need to implement doHead in order to handle HEAD requests (HEAD requests stipulate that the server should return the normal HTTP headers, but no associated document). You don't normally need to implement doHead because the system automatically calls doGet and uses the resultant status line and header settings to answer HEAD requests. However, it is occasionally useful to implement doHead so that you can generate responses to HEAD requests (i.e., requests from custom clients that want just the HTTP headers, not the actual document) more quickly—without building the actual document output.

The init Method

Most of the time, your servlets deal only with per-request data, and doGet or doPost are the only life-cycle methods you need. Occasionally, however, you want to perform complex setup tasks when the servlet is first loaded, but not repeat those tasks for each request. The init method is designed for this case; it is called when the servlet is first created, and *not* called again for each user request. So, it is used for one-time initializations, just as with the init method of applets. The servlet is normally created when a user first invokes a URL corresponding to the servlet, but you can also specify that the servlet be loaded when the server is first started (see the chapter on the web.xml file in Volume 2 of this book).

The init method definition looks like this:

```
public void init() throws ServletException {
  // Initialization code...
}
```

The init method performs two varieties of initializations: general initializations and initializations controlled by initialization parameters.

General Initializations

With the first type of initialization, init simply creates or loads some data that will be used throughout the life of the servlet, or it performs some one-time computation. If you are familiar with applets, this task is analogous to an applet calling getImage to load image files over the network: the operation only needs to be performed once, so it is triggered by init. Servlet examples include setting up a database connection pool for requests that the servlet will handle or loading a data file into a HashMap.

Listing 3.7 shows a servlet that uses init to do two things.

First, it builds an array of 10 integers. Since these numbers are based upon complex calculations, we don't want to repeat the computation for each request. So, doGet looks up the values that init computed, instead of generating them each time. The results of this technique are shown in Figure 3–6.

Second, since the output of the servlet does not change except when the server is rebooted, init also stores a page modification date that is used by the getLastModified method. This method should return a modification time expressed in milliseconds since 1970, as is standard with Java dates. The time is automatically converted to a date in GMT appropriate for the Last-Modified header. More importantly, if the server receives a conditional GET request (one specifying that the client only wants pages marked If-Modified-Since a particular date), the system compares the specified date to that returned by `getLastModified`, returning the page only if it has been changed after the specified date. Browsers frequently make these conditional requests for pages stored in their caches, so supporting conditional requests helps your users (they get faster results) and reduces server load (you send fewer complete documents). Since the `Last-Modified` and `If-Modified-Since` headers use only whole seconds, the `getLastModified` method should round times down to the nearest second.

Listing 3.7 coreservlets/LotteryNumbers.java

```
package coreservlets;

import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;

/** Example using servlet initialization and the
 *  getLastModified method.
 */

public class LotteryNumbers extends HttpServlet {
  private long modTime;
  private int[] numbers = new int[10];

  /** The init method is called only when the servlet is first
   *  loaded, before the first request is processed.
   */

  public void init() throws ServletException {
    // Round to nearest second (i.e., 1000 milliseconds)
    modTime = System.currentTimeMillis()/1000*1000;
    for(int i=0; i<numbers.length; i++) {
      numbers[i] = randomNum();
    }
  }

 /** Return the list of numbers that init computed. */

  public void doGet(HttpServletRequest request,
                    HttpServletResponse response)
      throws ServletException, IOException {
    response.setContentType("text/html");
    PrintWriter out = response.getWriter();
    String title = "Your Lottery Numbers";
    String docType =
      "<!DOCTYPE HTML PUBLIC \"-//W3C//DTD HTML 4.0 " +
      "Transitional//EN\">\n";
```

Listing 3.7 coreservlets/LotteryNumbers.java *(continued)*

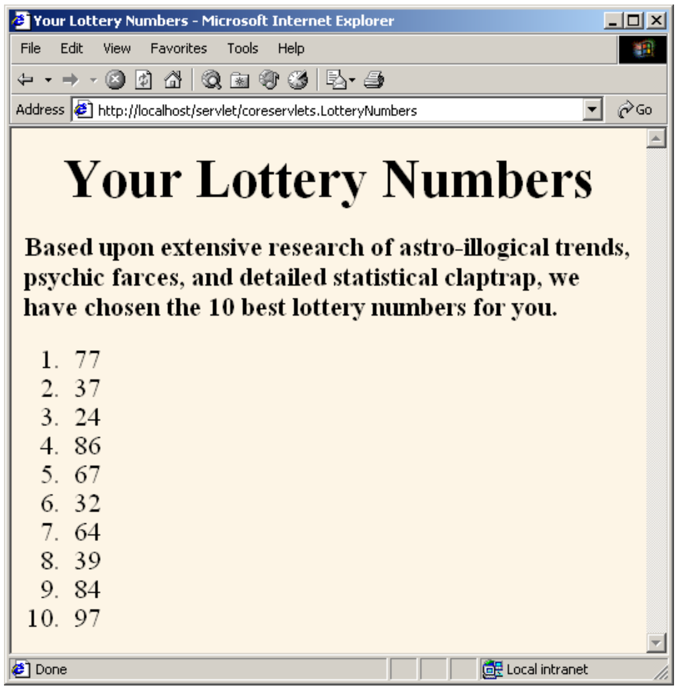
```
    out.println(docType +
                "<HTML>\n" +
                "<HEAD><TITLE>" + title + "</TITLE></HEAD>\n" +
                "<BODY BGCOLOR=\"#FDF5E6\">\n" +
                "<H1 ALIGN=CENTER>" + title + "</H1>\n" +
                "<B>Based upon extensive research of " +
                "astro-illogical trends, psychic farces, " +
                "and detailed statistical claptrap, " +
                "we have chosen the " + numbers.length +
                " best lottery numbers for you.</B>" +
                "<OL>");
    for(int i=0; i<numbers.length; i++) {
      out.println("  <LI>" + numbers[i]);
    }
    out.println("</OL>" +
                "</BODY></HTML>");
  }

  /** The standard service method compares this date against
   *  any date specified in the If-Modified-Since request header.
   *  If the getLastModified date is later or if there is no
   *  If-Modified-Since header, the doGet method is called
   *  normally. But if the getLastModified date is the same or
   *  earlier, the service method sends back a 304 (Not Modified)
   *  response and does <B>not</B> call doGet. The browser should
   *  use its cached version of the page in such a case.
   */

  public long getLastModified(HttpServletRequest request) {
    return(modTime);
  }

  // A random int from 0 to 99.

  private int randomNum() {
    return((int)(Math.random() * 100));
  }
}
```


Your Lottery Numbers - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Address http://localhost/servlet/coreservlets.LotteryNumbers
Go
Done
Local intranet

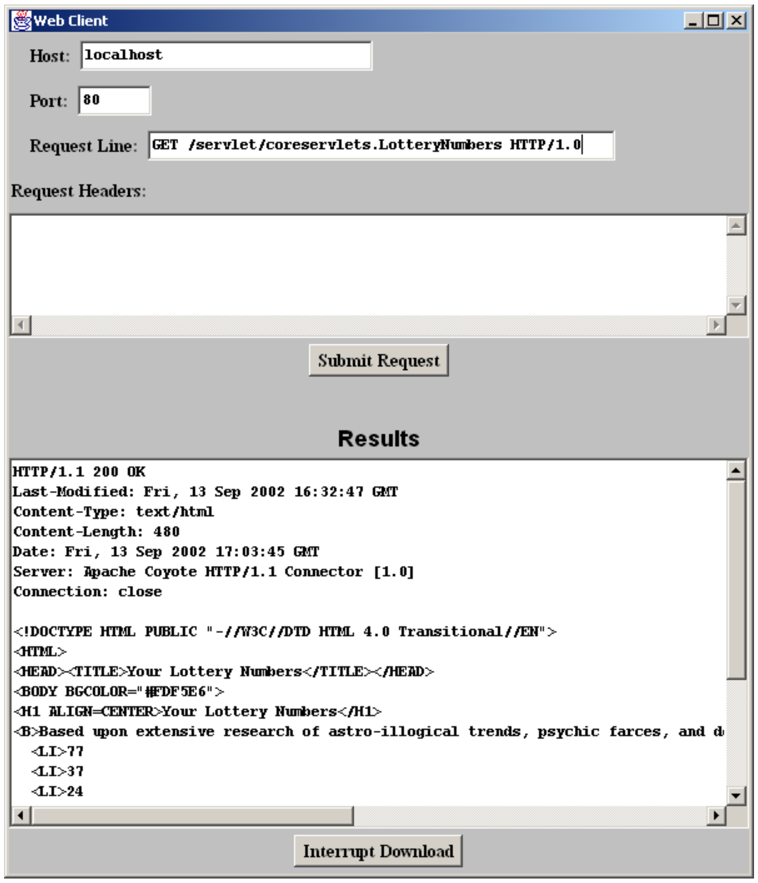
Your Lottery Numbers

Based upon extensive research of astro-illogical trends, psychic farces, and detailed statistical claptrap, we have chosen the 10 best lottery numbers for you.

1. 77
2. 37
3. 24
4. 86
5. 67
6. 32
7. 64
8. 39
9. 84
10. 97

Figure 3–6 Result of the `LotteryNumbers` servlet.

Figures 3–7 and 3–8 show the result of requests for the same servlet with two slightly different `If-Modified-Since` dates. To set the request headers and see the response headers, we used `WebClient`, a Java application that lets you interactively set up HTTP requests, submit them, and see the “raw” results. The code for `WebClient` is available at the source code archive on the book’s home page (http://www.coreservlets.com/).

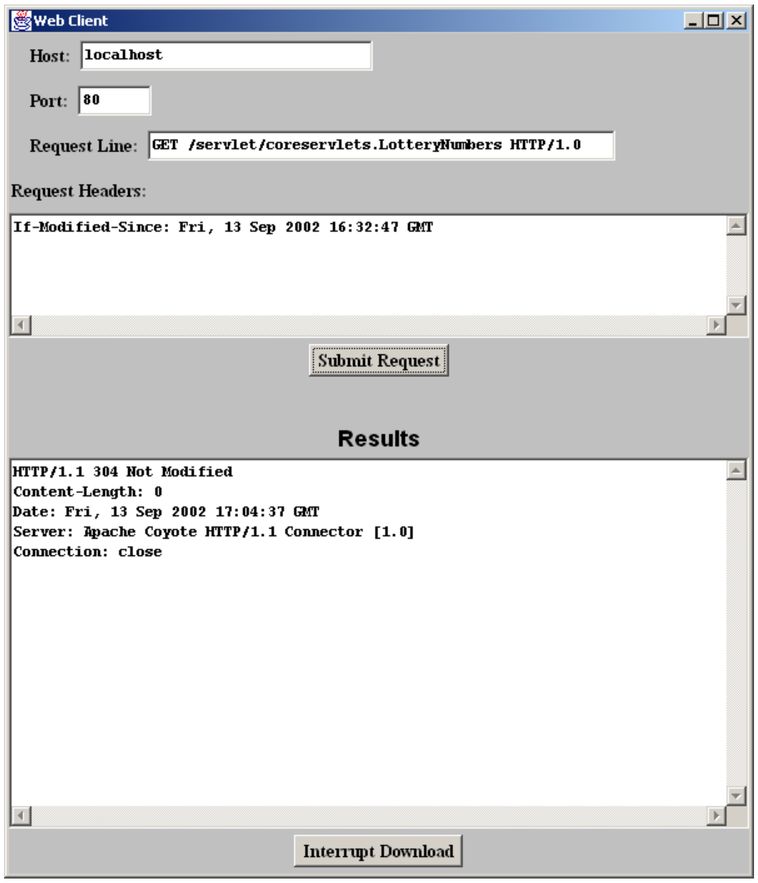


```
localhost
80
GET /servlet/coreservlets.LotteryNumbers HTTP/1.0
```

```
HTTP/1.1 200 OK
Last-Modified: Fri, 13 Sep 2002 16:32:47 GMT
Content-Type: text/html
Content-Length: 480
Date: Fri, 13 Sep 2002 17:03:45 GMT
Server: Apache Coyote HTTP/1.1 Connector [1.0]
Connection: close

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.0 Transitional//EN">
<HTML>
<HEAD><TITLE>Your Lottery Numbers</TITLE></HEAD>
<BODY BGCOLOR="#FDF5E6">
<H1 ALIGN=CENTER>Your Lottery Numbers</H1>
<B>Based upon extensive research of astro-illogical trends, psychic farces, and d
  <LI>77
  <LI>37
  <LI>24
```

Figure 3–7 Accessing the `LotteryNumbers` servlet results in normal response (with the document sent to the client) in two situations: when there is an unconditional `GET` request or when there is a conditional request that specifies a date before servlet initialization. Code for the `WebClient` program (used here to interactively connect to the server) is available at the book's source code archive at http://www.coreservlets.com/.



```
localhost
80
GET /servlet/coreservlets.LotteryNumbers HTTP/1.0
If-Modified-Since: Fri, 13 Sep 2002 16:32:47 GMT
```

```
HTTP/1.1 304 Not Modified
Content-Length: 0
Date: Fri, 13 Sep 2002 17:04:37 GMT
Server: Apache Coyote HTTP/1.1 Connector [1.0]
Connection: close
```

Figure 3–8 Accessing the `LotteryNumbers` servlet results in a 304 (Not Modified) response with no actual document in one situation: when a conditional `GET` request is received that specifies a date at or after servlet initialization.

Initializations Controlled by Initialization Parameters

In the previous example, the `init` method computed some data that was used by the `doGet` and `getLastModified` methods. Although this type of general initialization is quite common, it is also common to control the initialization by the use of initialization parameters. To understand the motivation for init parameters, you need to understand the categories of people who might want to customize the way a servlet or JSP page behaves. There are three such groups:

1. Developers.
2. End users.
3. Deployers.

Developers change the behavior of a servlet by changing the code. End users change the behavior of a servlet by providing data to an HTML form (assuming that the developer has written the servlet to look for this data). But what about deployers? There needs to be a way to let administrators move servlets from machine to machine and change certain parameters (e.g., the address of a database, the size of a connection pool, or the location of a data file) without modifying the servlet source code. Providing this capability is the purpose of init parameters.

Because the use of servlet initialization parameters relies heavily on the deployment descriptor (web.xml), we postpone details and examples on init parameters until the deployment descriptor chapter in Volume 2 of this book. But, here is a brief preview:

1. Use the web.xml `servlet` element to give a name to your servlet.
2. Use the web.xml `servlet-mapping` element to assign a custom URL to your servlet. You never use default URLs of the form http://.../**servlet**/*ServletName* when using init parameters. In fact, these default URLs, although extremely convenient during initial development, are almost never used in deployment scenarios.
3. Add `init-param` subelements to the web.xml `servlet` element to assign names and values of initialization parameters.
4. From within your servlet's `init` method, call `getServletConfig` to obtain a reference to the `ServletConfig` object.
5. Call the `getInitParameter` method of `ServletConfig` with the name of the init parameter. The return value is the value of the init parameter or `null` if no such init parameter is found in the web.xml file.

The destroy Method

The server may decide to remove a previously loaded servlet instance, perhaps because it is explicitly asked to do so by the server administrator or perhaps because the servlet is idle for a long time. Before it does, however, it calls the servlet's `destroy` method. This method gives your servlet a chance to close database connections, halt background threads, write cookie lists or hit counts to disk, and perform other such cleanup activities. Be aware, however, that it is possible for the Web server to crash (remember those California power outages?). So, don't count on `destroy` as the *only* mechanism for saving state to disk. If your servlet performs activities like counting hits or accumulating lists of cookie values that indicate special access, you should also proactively write the data to disk periodically.

3.7 The SingleThreadModel Interface

Normally, the system makes a single instance of your servlet and then creates a new thread for each user request. This means that if a new request comes in while a previous request is still executing, multiple threads can concurrently be accessing the same servlet object. Consequently, your `doGet` and `doPost` methods must be careful to synchronize access to fields and other shared data (if any) since multiple threads may access the data simultaneously. Note that local variables are not shared by multiple threads, and thus need no special protection.

In principle, you can prevent multithreaded access by having your servlet implement the `SingleThreadModel` interface, as below.

```
public class YourServlet extends HttpServlet
    implements SingleThreadModel {
  ...
}
```

If you implement this interface, the system guarantees that there is never more than one request thread accessing a single instance of your servlet. In most cases, it does so by queuing all the requests and passing them one at a time to a single servlet instance. However, the server is permitted to create a pool of multiple instances, each of which handles one request at a time. Either way, this means that you don't have to worry about simultaneous access to regular fields (instance variables) of the servlet. You *do*, however, still have to synchronize access to class variables (`static` fields) or shared data stored outside the servlet.

Although `SingleThreadModel` prevents concurrent access in principle, in practice there are two reasons why it is usually a poor choice.

First, synchronous access to your servlets can significantly hurt performance (latency) if your servlet is accessed frequently. When a servlet waits for I/O, the server cannot handle pending requests for the same servlet. So, think twice before using the `SingleThreadModel` approach. Instead, consider synchronizing only the part of the code that manipulates the shared data.

The second problem with `SingleThreadModel` stems from the fact that the specification permits servers to use pools of instances instead of queueing up the requests to a single instance. As long as each instance handles only one request at a time, the pool-of-instances approach satisfies the requirements of the specification. But, it is a bad idea.

Suppose, on one hand, that you are using regular non-static instance variables (fields) to refer to shared data. Sure, `SingleThreadModel` prevents concurrent access, but it does so by throwing out the baby with the bath water: each servlet instance has a separate copy of the instance variables, so the data is no longer shared properly.

On the other hand, suppose that you are using static instance variables to refer to the shared data. In that case, the pool-of-instances approach to `SingleThreadModel` provides no advantage whatsoever; multiple requests (using different instances) can still concurrently access the static data.

Now, `SingleThreadModel` is still occasionally useful. For example, it can be used when the instance variables are reinitialized for each request (e.g., when they are used merely to simplify communication among methods). But, the problems with `SingleThreadModel` are so severe that it is deprecated in the servlet 2.4 (JSP 2.0) specification. You are much better off using explicit `synchronized` blocks.

Core Warning

Avoid implementing `SingleThreadModel` for high-traffic servlets. Use it with great caution at other times. For production-level code, explicit code synchronization is almost always better. `SingleThreadModel` is deprecated in version 2.4 of the servlet specification.

For example, consider the servlet of Listing 3.8 that attempts to assign unique user IDs to each client (unique until the server restarts, that is). It uses an instance variable (field) called `nextID` to keep track of which ID should be assigned next, and uses the following code to output the ID.

```
String id = "User-ID-" + nextID;
out.println("<H2>" + id + "</H2>");
nextID = nextID + 1;
```

Now, suppose you were very careful in testing this servlet. You put it in a subdirectory called **coreservlets**, compiled it, and copied the **coreservlets** directory to the **WEB-INF/classes** directory of the default Web application (see Section 2.10, "Deployment Directories for Default Web Application: Summary"). You started the server. You repeatedly accessed the servlet with **http://localhost/servlet/coreservlets.UserIDs**. Every time you accessed it, you got a different value (Figure 3–9). So the code is correct, right? Wrong! The problem occurs only when there are multiple simultaneous accesses to the servlet. Even then, it occurs only once in a while. But, in a few cases, the first client could read the `nextID` field and have its thread preempted before it incremented the field. Then, a second client could read the field and get the same value as the first client. Big trouble! For example, there have been real-world e-commerce applications where customer purchases were occasionally charged to the wrong client's credit card, precisely because of such a race condition in the generation of user IDs.

Now, if you are familiar with multithreaded programming, the problem was very obvious to you. The question is, what is the proper solution? Here are three possibilities.

1. **Shorten the race.** Remove the third line of the code snippet and change the first line to the following.

   ```
   String id = "User-ID-" + nextID++;
   ```

   Boo! This approach decreases the likelihood of an incorrect answer, but does not eliminate the possibility. In many scenarios, lowering the probability of a wrong answer is a bad thing, not a good thing: it merely means that the problem is less likely to be detected in testing, and more likely to occur after being fielded.
2. **Use `SingleThreadModel`.** Change the servlet class definition to the following.

   ```
   public class UserIDs extends HttpServlet
                            implements SingleThreadModel {
   ```

   Will this work? If the server implements `SingleThreadModel` by queueing up all the requests, then, yes, this will work. But at a performance cost if there is a lot of concurrent access. Even worse, if the server implements `SingleThreadModel` by making a pool of servlet instances, this approach will totally fail because each instance will have its own `nextID` field. Either server implementation approach is legal, so this "solution" is no solution at all.
3. **Synchronize the code explicitly.** Use the standard synchronization construct of the Java programming language. Start a `synchronized` block just before the first access to the shared data, and end the block just after the last update to the data, as follows.

   ```
   synchronized(this) {
     String id = "User-ID-" + nextID;
     out.println("<H2>" + id + "</H2>");
     nextID = nextID + 1;
   }
   ```

   This technique tells the system that, once a thread has entered the above block of code (or any other `synchronized` section labelled with the same object reference), no other thread is allowed in until the first thread exits. This is the solution you have always used in the Java programming language. It is the right one here, too. Forget error-prone and low-performance `SingleThreadModel` shortcuts; fix race conditions the right way.

Listing 3.8 coreservlets/UserIDs.java

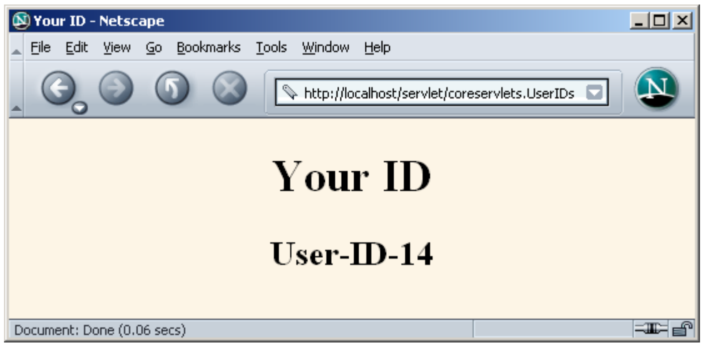
```
package coreservlets;

import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;

/** Servlet that attempts to give each user a unique
 *  user ID. However, because it fails to synchronize
 *  access to the nextID field, it suffers from race
 *  conditions: two users could get the same ID.
 */

public class UserIDs extends HttpServlet {
  private int nextID = 0;

  public void doGet(HttpServletRequest request,
                    HttpServletResponse response)
      throws ServletException, IOException {
    response.setContentType("text/html");
    PrintWriter out = response.getWriter();
    String title = "Your ID";
    String docType =
      "<!DOCTYPE HTML PUBLIC \"-//W3C//DTD HTML 4.0 " +
      "Transitional//EN\">\n";
    out.println(docType +
                "<HTML>\n" +
                "<HEAD><TITLE>" + title + "</TITLE></HEAD>\n" +
                "<CENTER>\n" +
                "<BODY BGCOLOR=\"#FDF5E6\">\n" +
                "<H1>" + title + "</H1>\n");
    String id = "User-ID-" + nextID;
    out.println("<H2>" + id + "</H2>");
    nextID = nextID + 1;
    out.println("</BODY></HTML>");
  }
}
```


Your ID - Netscape
File Edit View Go Bookmarks Tools Window Help
http://localhost/servlet/coreservlets.UserIDs

Your ID

User-ID-14

Document: Done (0.06 secs)

Figure 3–9 Result of the `UserIDs` servlet.

3.8 Servlet Debugging

Naturally, when *you* write servlets, you never make mistakes. However, some of your colleagues might make an occasional error, and you can pass this advice on to them. Seriously, though, debugging servlets can be tricky because you don't execute them directly. Instead, you trigger their execution by means of an HTTP request, and they are executed by the Web server. This remote execution makes it difficult to insert break points or to read debugging messages and stack traces. So, approaches to servlet debugging differ somewhat from those used in general development. Here are 10 general strategies that can make your life easier.

1. **Use print statements.**
   With most server vendors, if you run the server on your desktop, a window pops up that displays standard output (i.e., the result of `System.out.println` statements). "What?" you say, "Surely you aren't advocating something as old-fashioned as print statements?" Well, true, there are more sophisticated debugging techniques. And if you are familiar with them, by all means use them. But you'd be surprised how useful it is to just gather basic information about how your program is operating. The `init` method doesn't seem to work? Insert a print statement, restart the server, and see if the print statement is displayed in the standard output window. Perhaps you declared `init` incorrectly, so your version isn't being called? Get a `NullPointerException`? Insert a couple of print statements to find out which line of code generated the error and which object on that line was `null`. When in doubt, gather more information.

2. **Use an integrated debugger in your IDE.**
   Many integrated development environments (IDEs) have sophisticated debugging tools that can be integrated with your servlet and JSP container. The Enterprise editions of IDEs like Borland JBuilder, Oracle JDeveloper, IBM WebSphere Studio, Eclipse, BEA WebLogic Studio, Sun ONE Studio, etc., typically let you insert breakpoints, trace method calls, and so on. Some will even let you connect to a server running on a remote system.
3. **Use the log file.**
   The `HttpServlet` class has a method called `log` that lets you write information into a logging file on the server. Reading debugging messages from the log file is a bit less convenient than watching them directly from a window as with the two previous approaches, but using the log file is an option even when running on a remote server; in such a situation, print statements are rarely useful and only the advanced IDEs support remote debugging. The `log` method has two variations: one that takes a `String`, and the other that takes a `String` and a `Throwable` (an ancestor class of `Exception`). The exact location of the log file is server-specific, but is generally clearly documented or can be found in subdirectories of the server installation directory.
4. **Use Apache Log4J.**
   Log4J is a package from the Apache Jakarta Project—the same project that manages Tomcat (one of the sample servers used in the book) and Struts (an MVC framework discussed in Volume 2 of this book). With Log4J, you semi-permanently insert debugging statements in your code and use an XML-based configuration file to control which are invoked at request time. Log4J is fast, flexible, convenient, and becoming more popular by the day. For details, see http://jakarta.apache.org/log4j/.
5. **Write separate classes.**
   One of the basic principles of good software design is to put commonly used code into a separate function or class so you don't need to keep rewriting it. That principle is even more important when you are writing servlets, since these separate classes can often be tested independently of the server. You can even write a test routine, with a `main`, that can be used to generate hundreds or thousands of test cases for your routines—not something you are likely to do if you have to submit each test case by hand in a browser.
6. **Plan ahead for missing or malformed data.**
   Are you reading form data from the client (Chapter 4)? Remember to check whether it is `null` or an empty string. Are you processing HTTP request headers (Chapter 5)? Remember that the headers are optional and thus might be `null` in any particular request. Every time

you
process data that comes directly or indirectly from a client, be sure to consider the possibility that it was entered incorrectly or omitted altogether.

7. **Look at the HTML source.**
If the result you see in the browser looks odd, choose View Source from the browser's menu. Sometimes a small HTML error like `<TABLE>` instead of `</TABLE>` can prevent much of the page from being viewed. Even better, use a formal HTML validator on the servlet's output. See Section 3.5 (Simple HTML-Building Utilities) for a discussion of this approach.
8. **Look at the request data separately.**
Servlets read data from the HTTP request, construct a response, and send it back to the client. If something in the process goes wrong, you want to discover if the cause is that the client is sending the wrong data or that the servlet is processing it incorrectly. The `EchoServer` class, discussed in Chapter 19 (Creating and Processing HTML Forms), lets you submit HTML forms and get a result that shows you *exactly* how the data arrived at the server. This class is merely a simple HTTP server that, for all requests, constructs an HTML page showing what was sent. Full source code is online at http://www.coreservlets.com/.
9. **Look at the response data separately.**
Once you look at the request data separately, you'll want to do the same for the response data. The `WebClient` class, discussed in the `init` example of Section 3.6 (The Servlet Life Cycle), lets you connect to the server interactively, send custom HTTP request data, and see everything that comes back—HTTP response headers and all. Again, you can download the source code from http://www.coreservlets.com/.
10. **Stop and restart the server.**
Servers are supposed to keep servlets in memory between requests, not reload them each time they are executed. However, most servers support a development mode in which servlets are supposed to be automatically reloaded whenever their associated class file changes. At times, however, some servers can get confused, especially when your only change is to a lower-level class, not to the top-level servlet class. So, if it appears that changes you make to your servlets are not reflected in the servlet's behavior, try restarting the server. Similarly, the `init` method is run only when a servlet is first loaded, the web.xml file (see Section 2.11) is read only when a Web application is first loaded (although many servers have a custom extension for reloading it), and certain Web application listeners (see Volume 2) are triggered only when the server first starts. Restarting the server will simplify debugging in all of those situations.